Starlight Reshapes Planetary Nurseries

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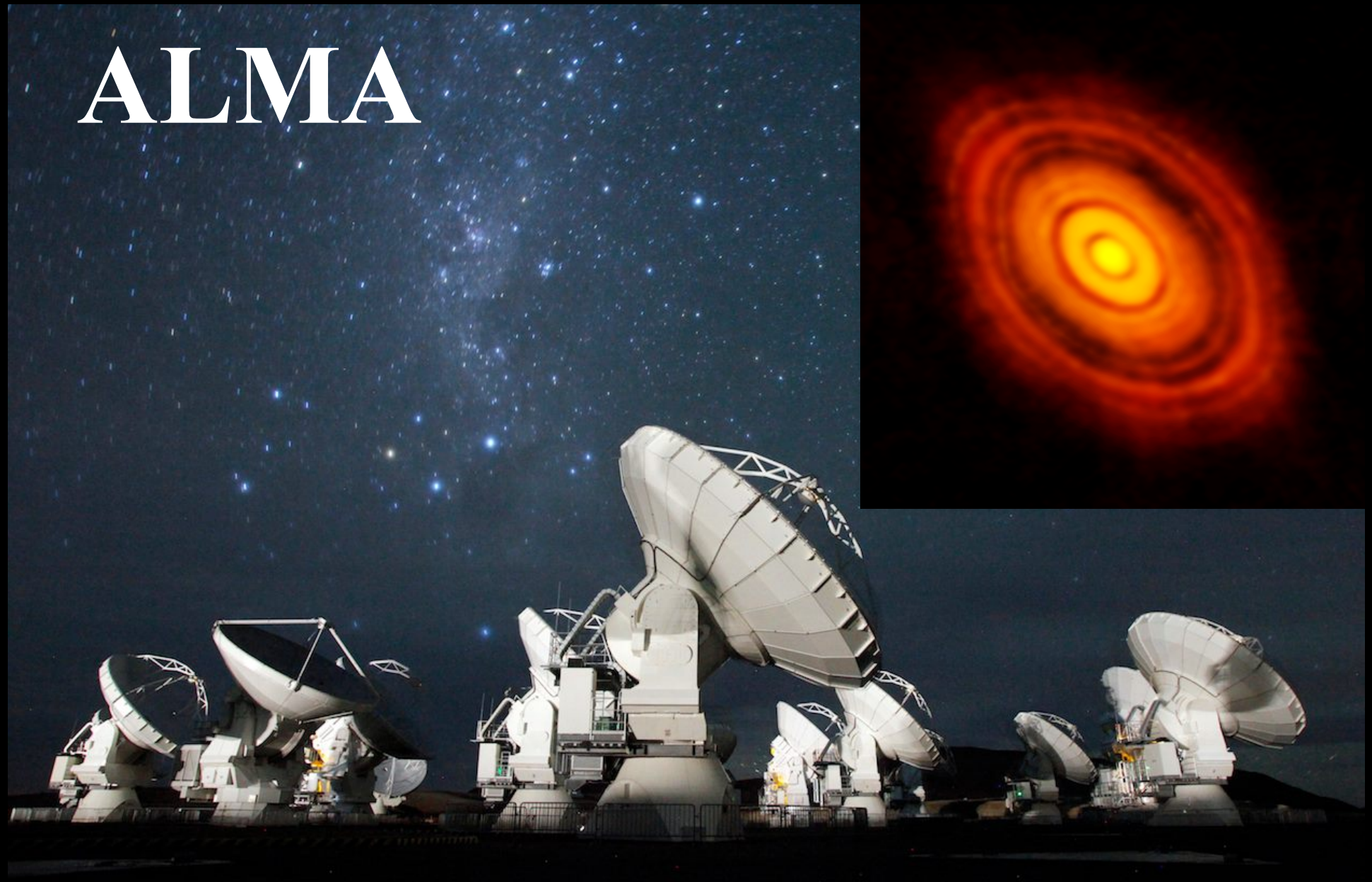
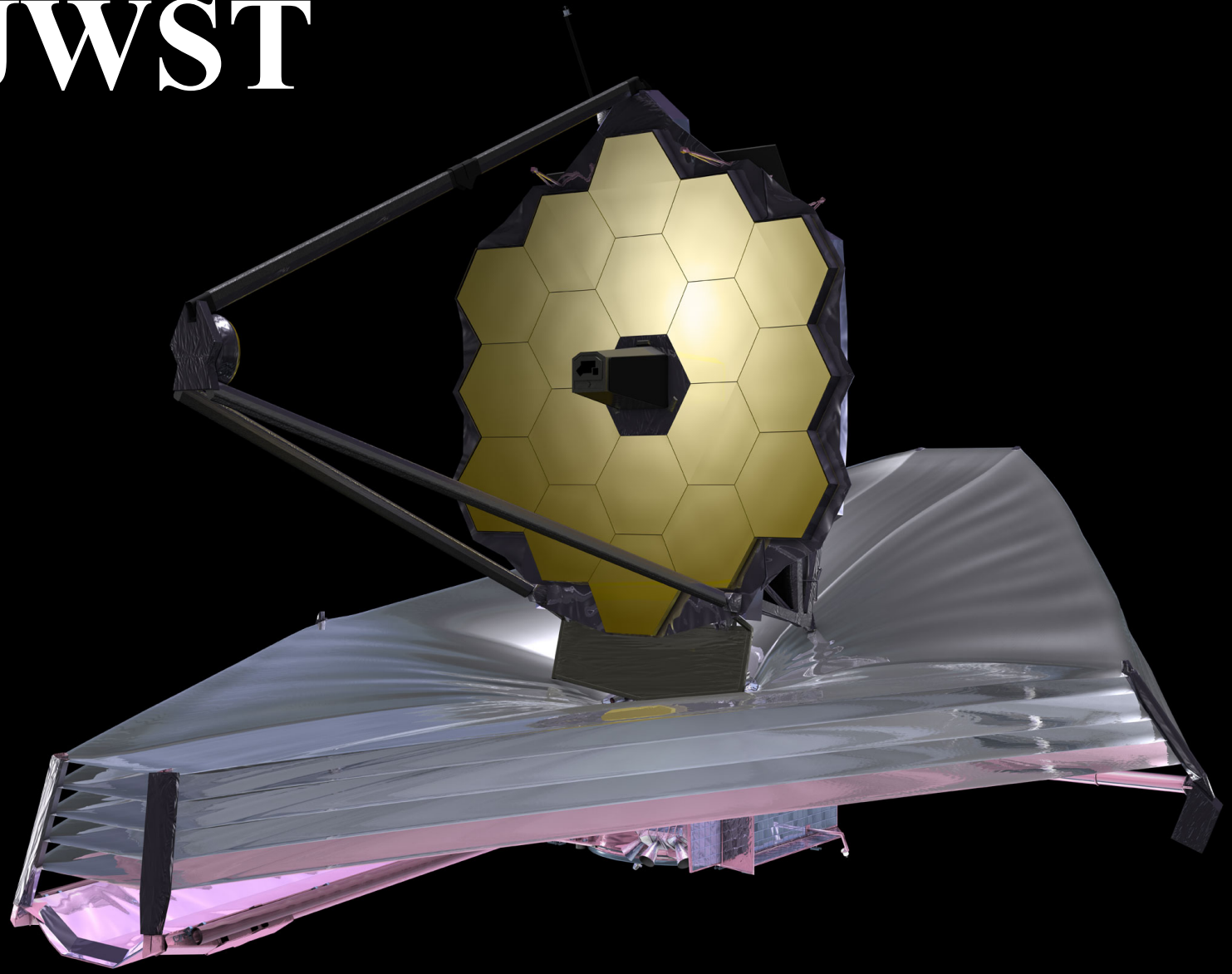
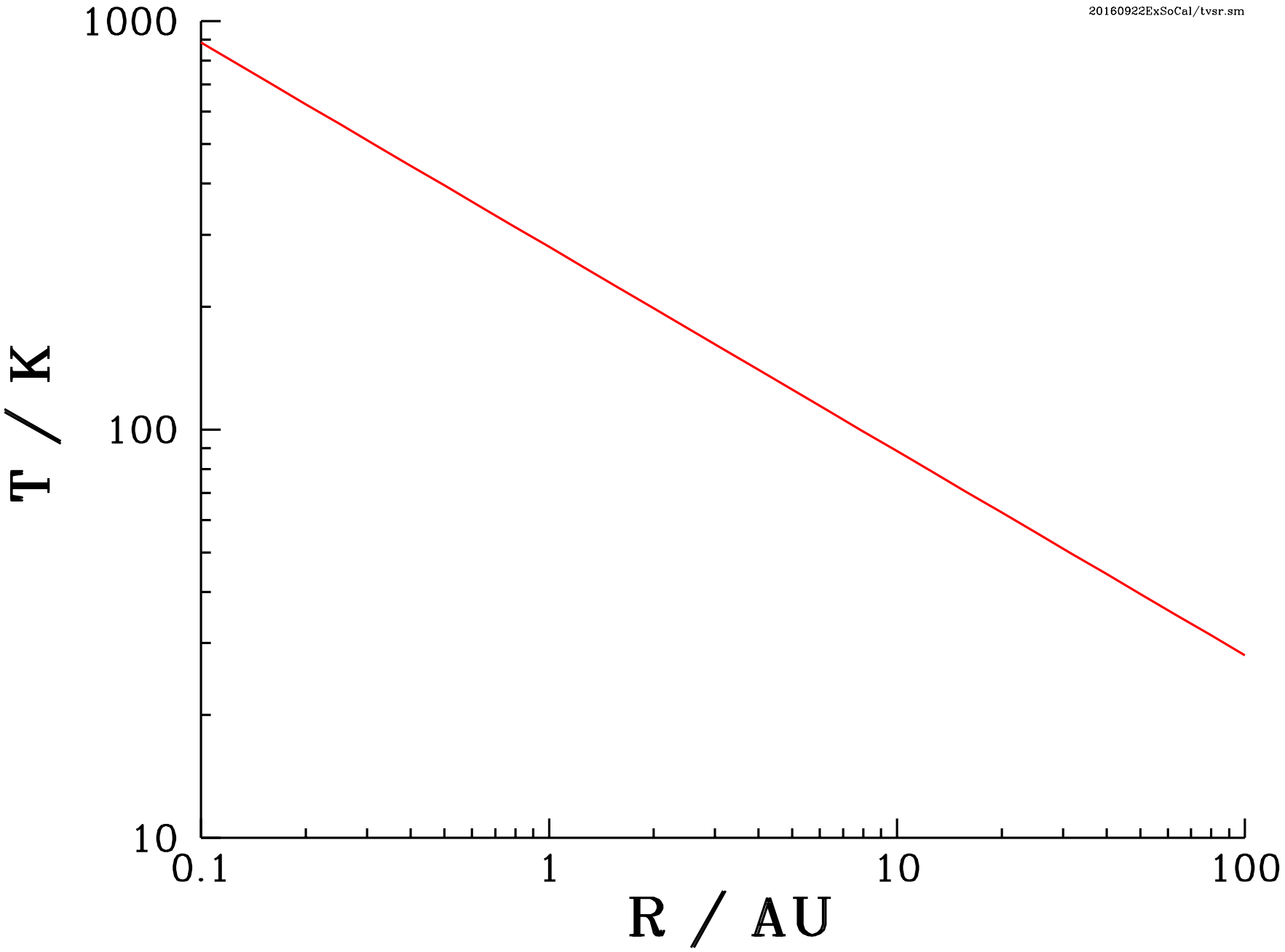
Artwork by W. K. Hartmann

ALMA



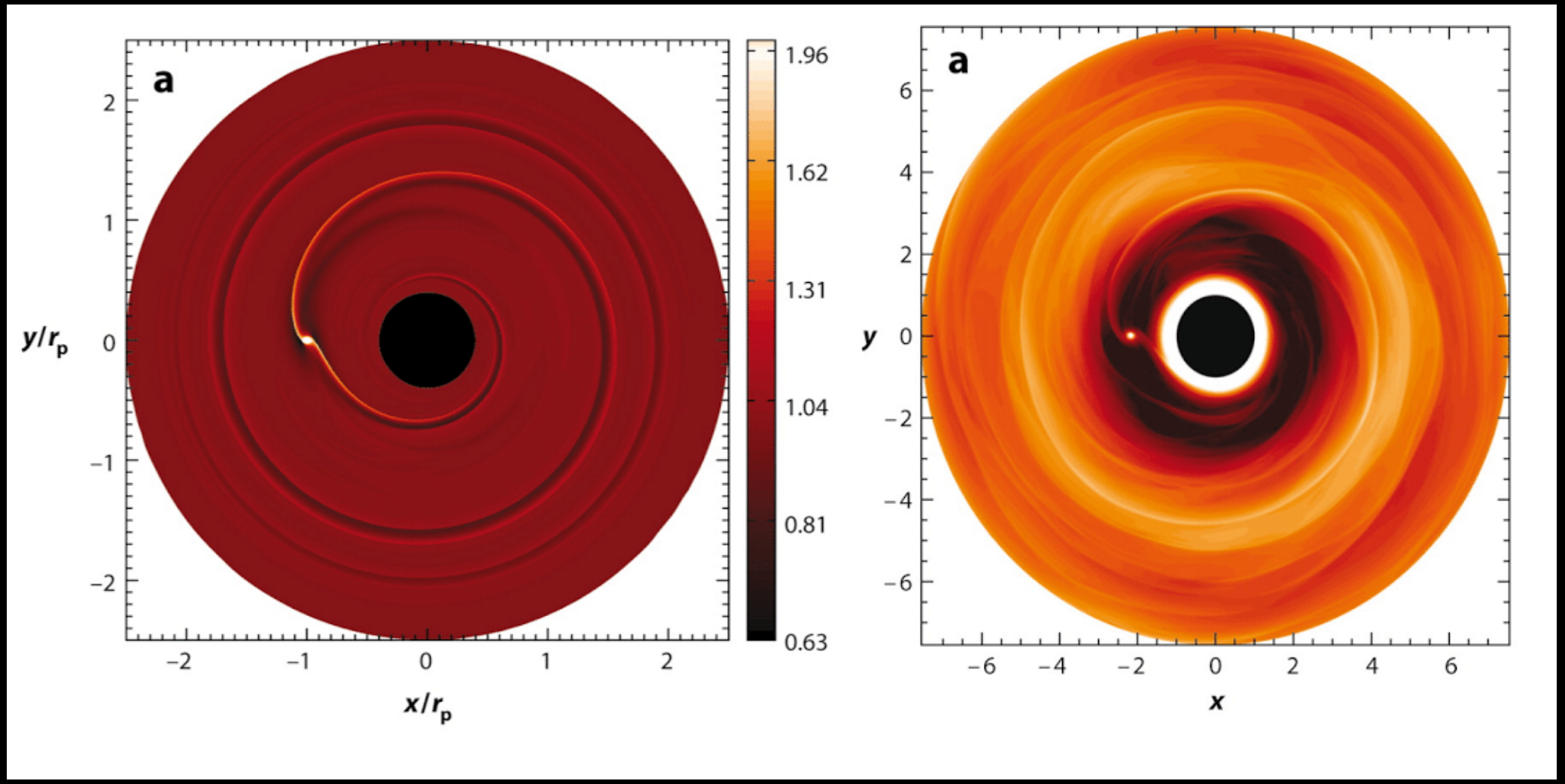
JWST



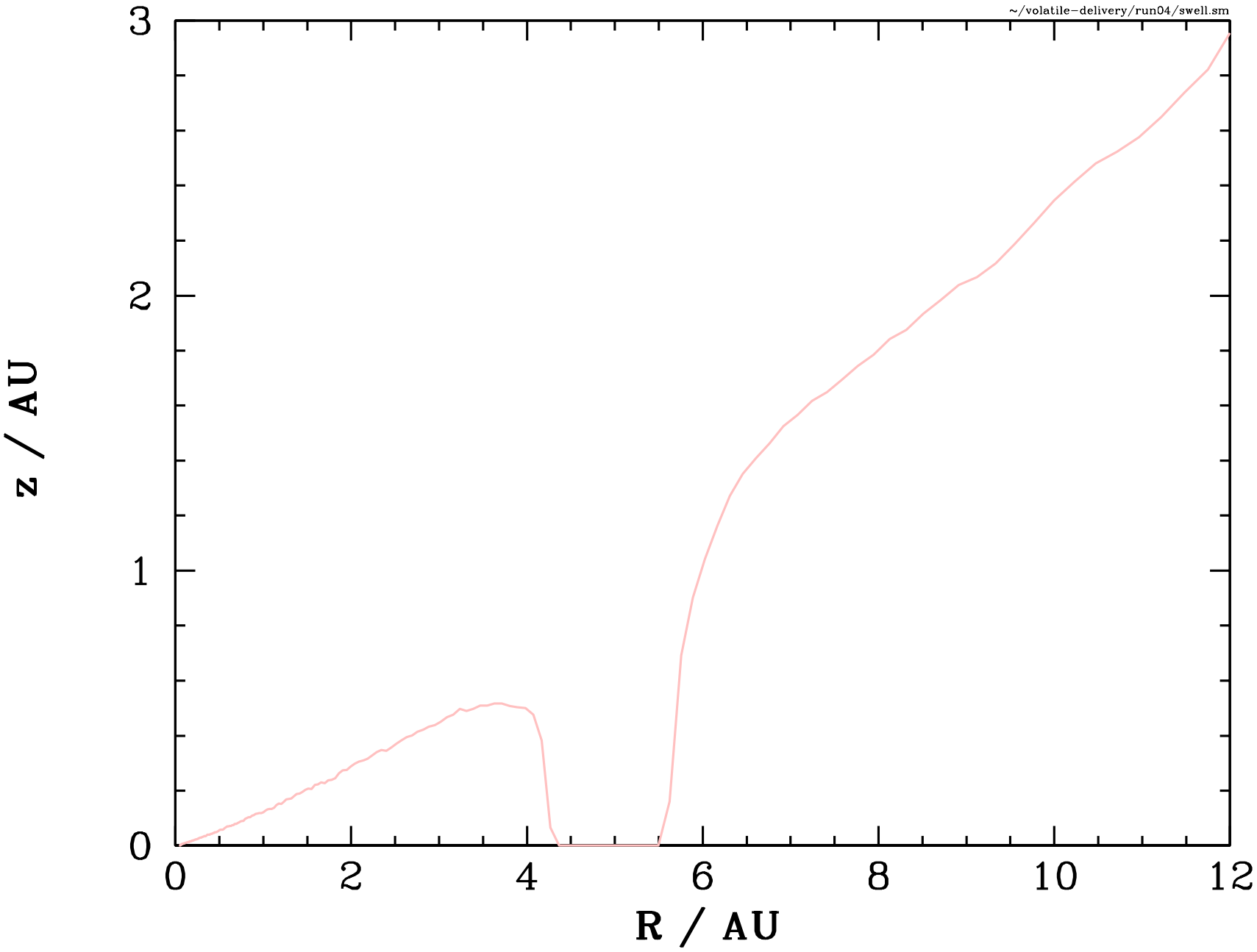

20160922ExSoCal/tvsr.sm
1000
100
10
T / K
0.1
1
10
100
R / AU

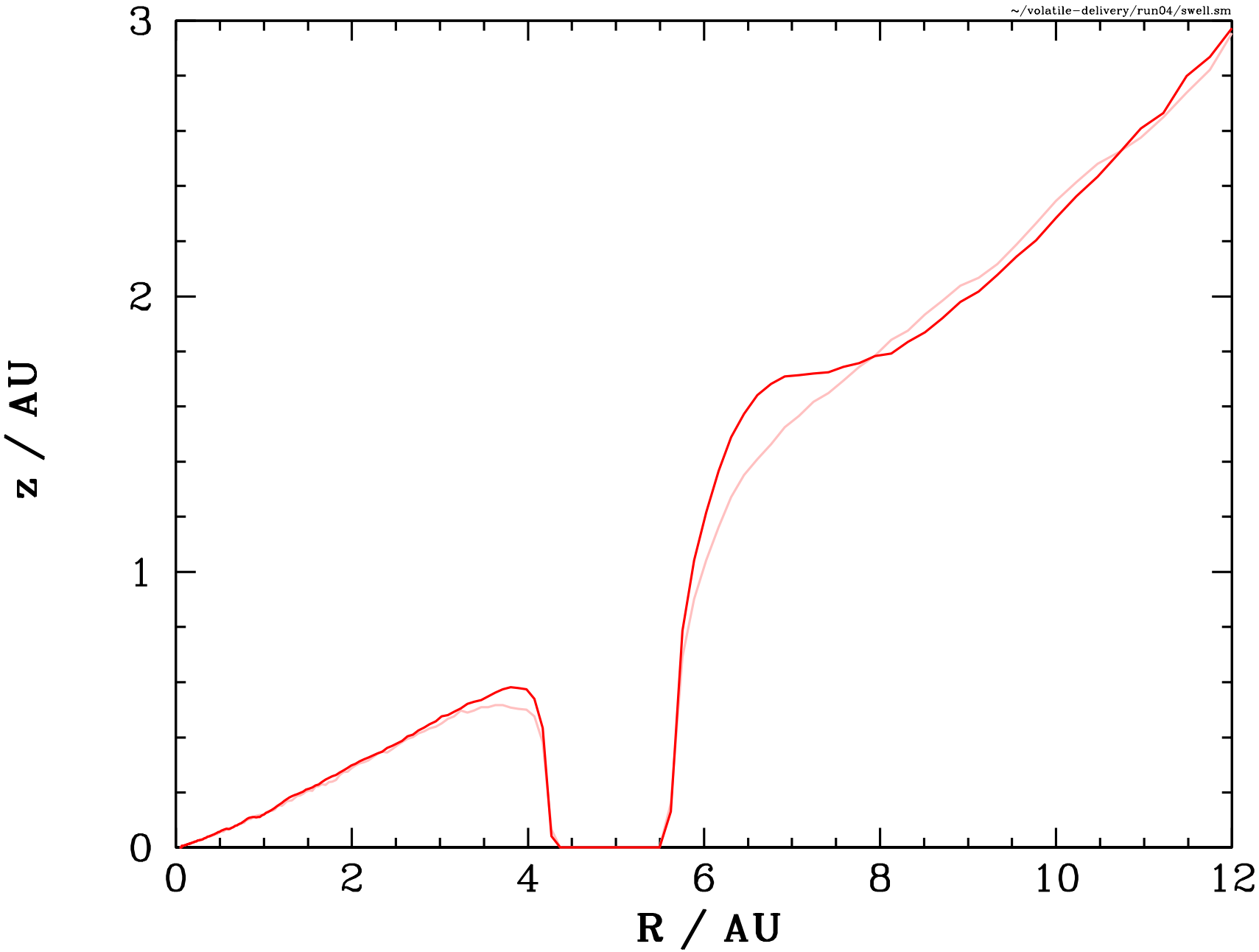
Neptune

Super-Jupiter



P. Armitage; Kley & Nelson 2012


~/volatile-delivery/run04/swell.sm
z / AU
R / AU
0
1
2
3
0
2
4
6
8
10
12


~/volatile-delivery/run04/swell.sm
z / AU
R / AU
0
1
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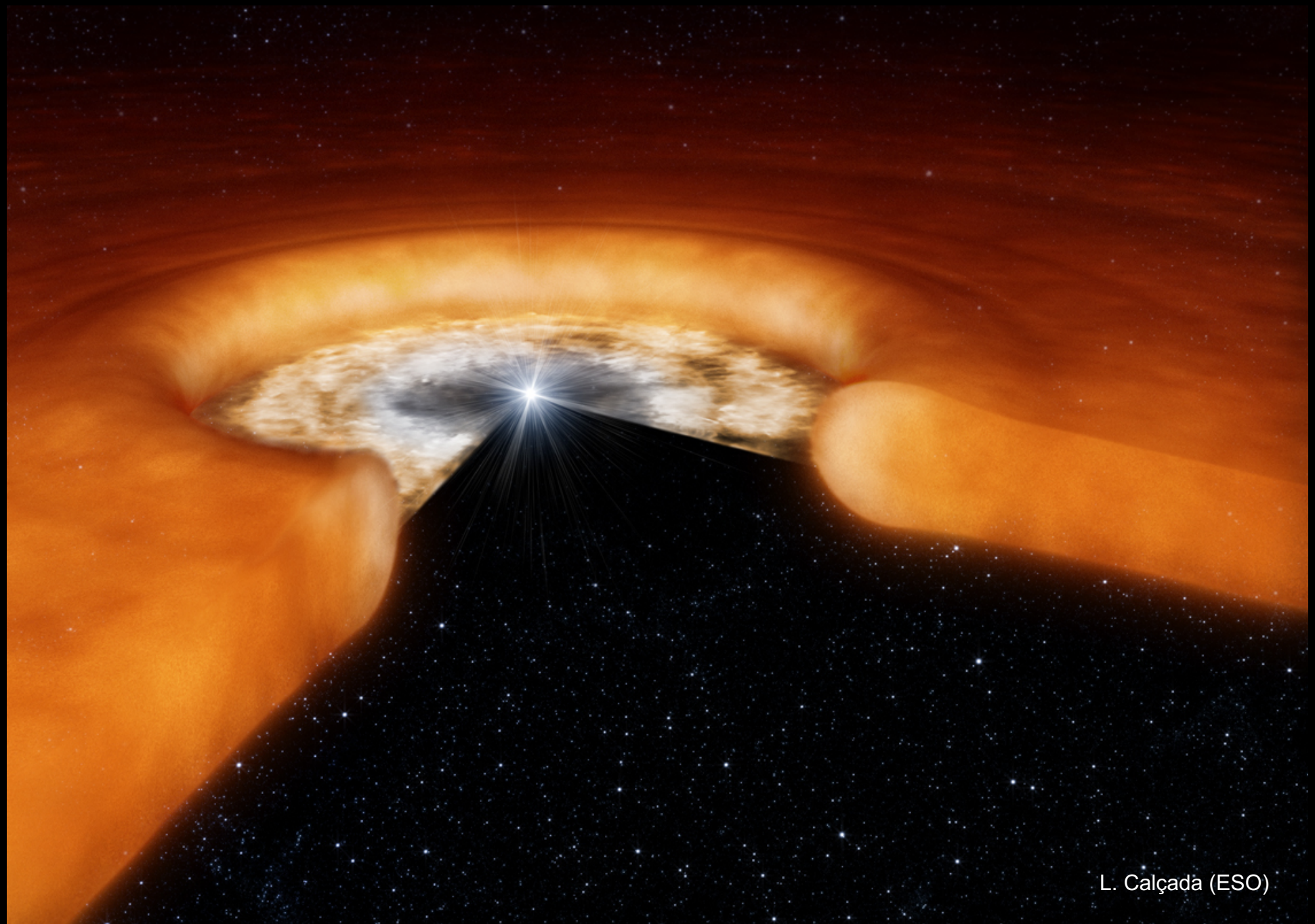
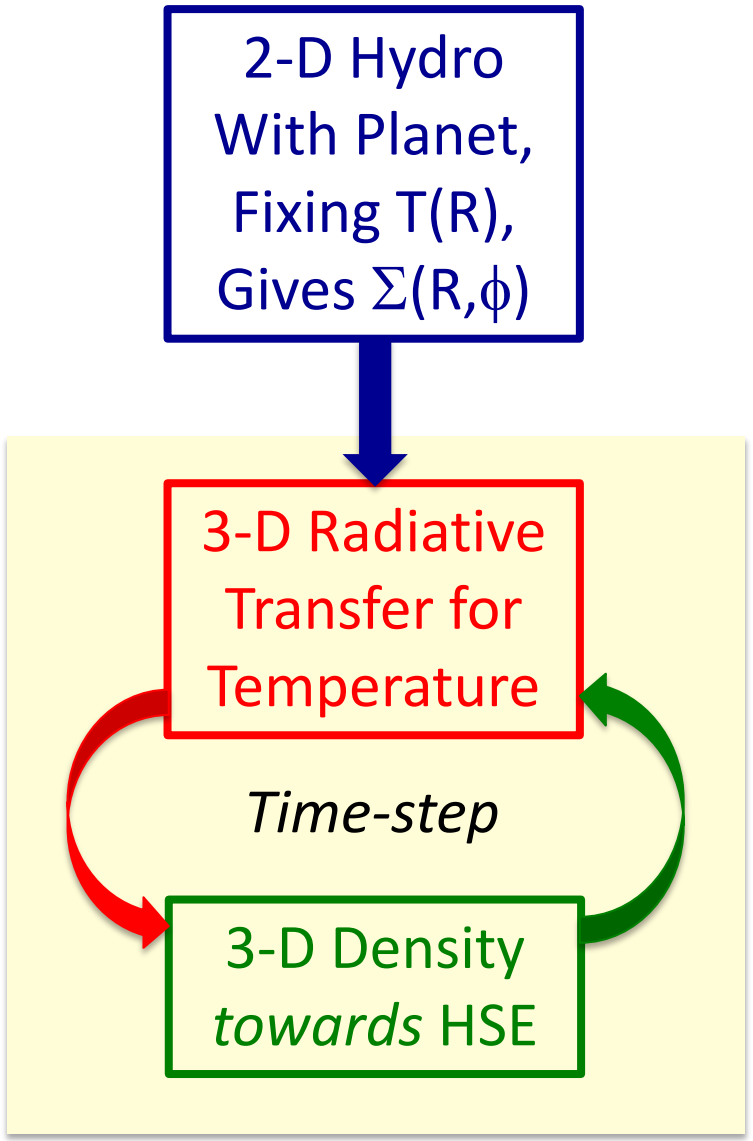
3
0
2
4
6
8
10
12


L. Calçada (ESO)


2-D Hydro
With Planet,
Fixing T(R),
Gives Σ(R,ϕ)
3-D Radiative
Transfer for
Temperature
Time-step
3-D Density
towards HSE

Two Timescales

$$t_{dy} = \frac{2\pi}{\Omega} \propto r^{3/2}$$

$$t_{th} \approx \frac{c_s^2 \Sigma}{\sigma T^4} \propto r^{1/2}$$

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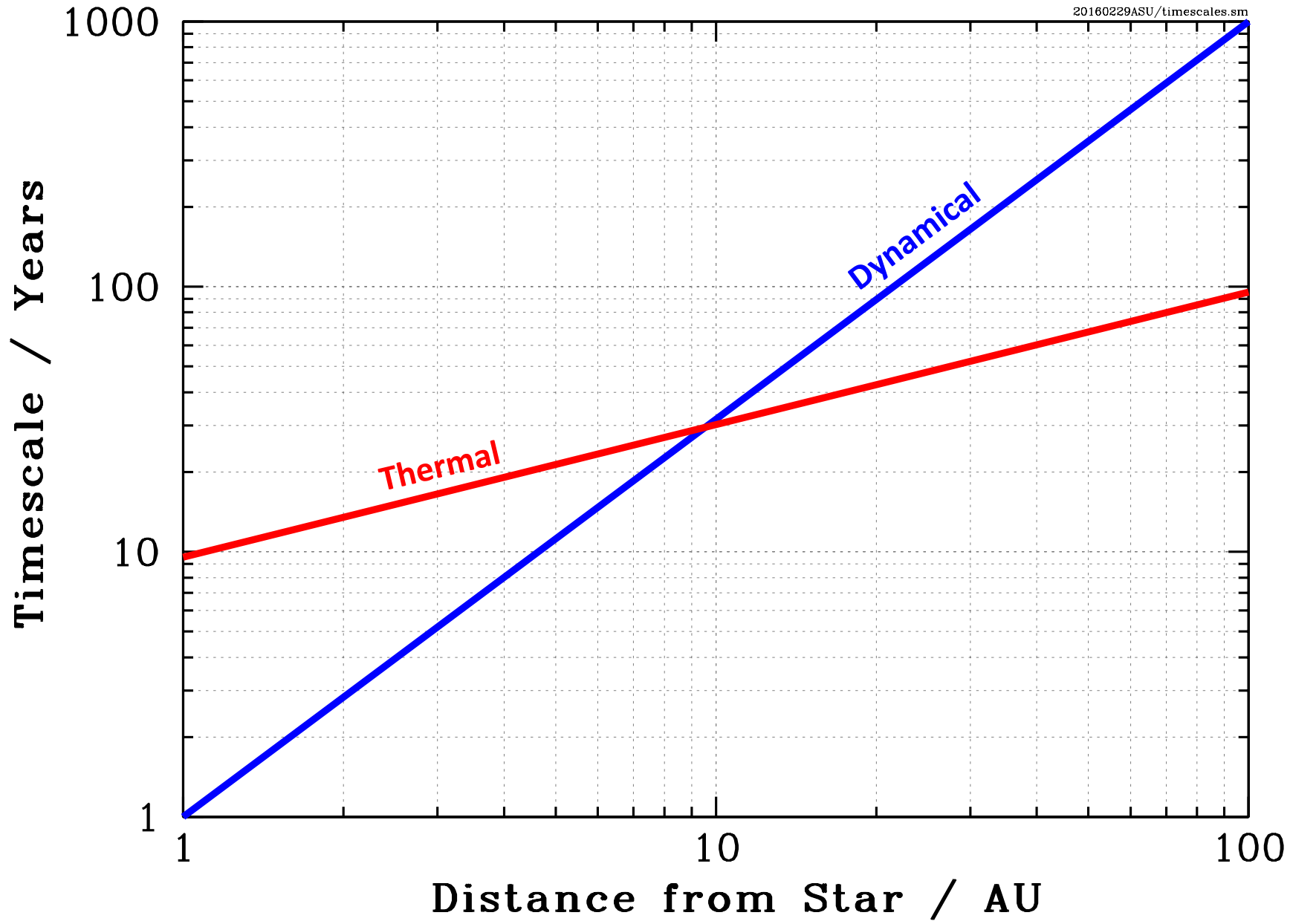
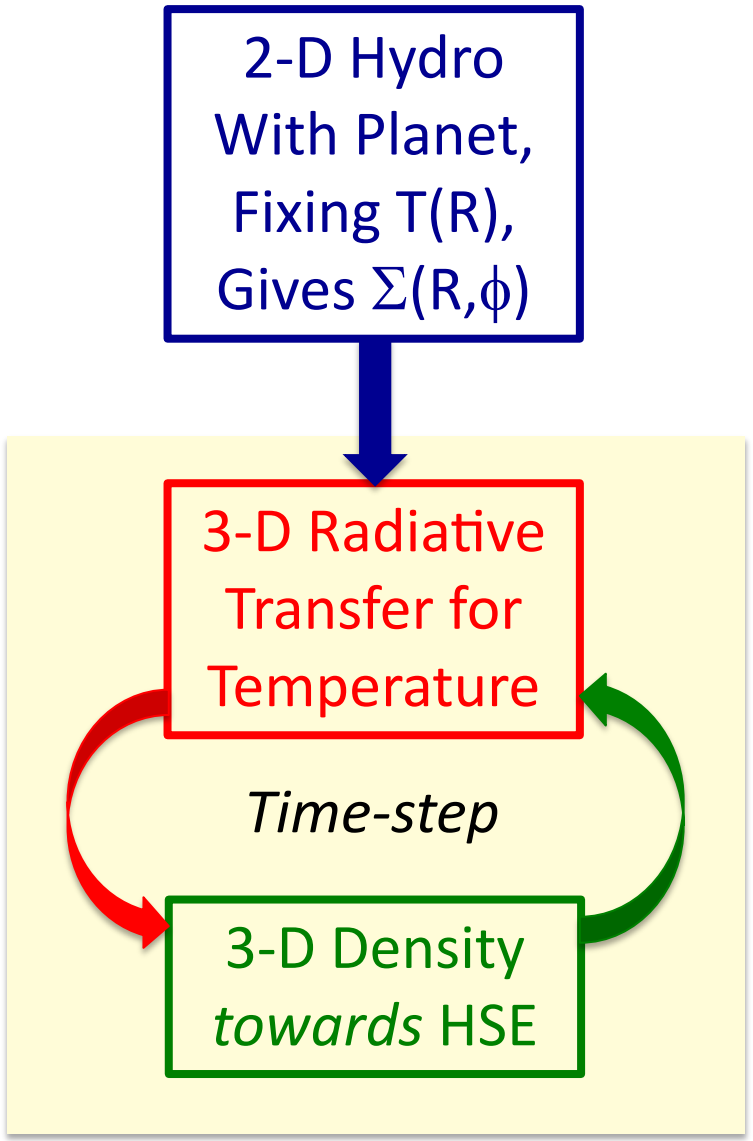
Watanabe & Lin 2008

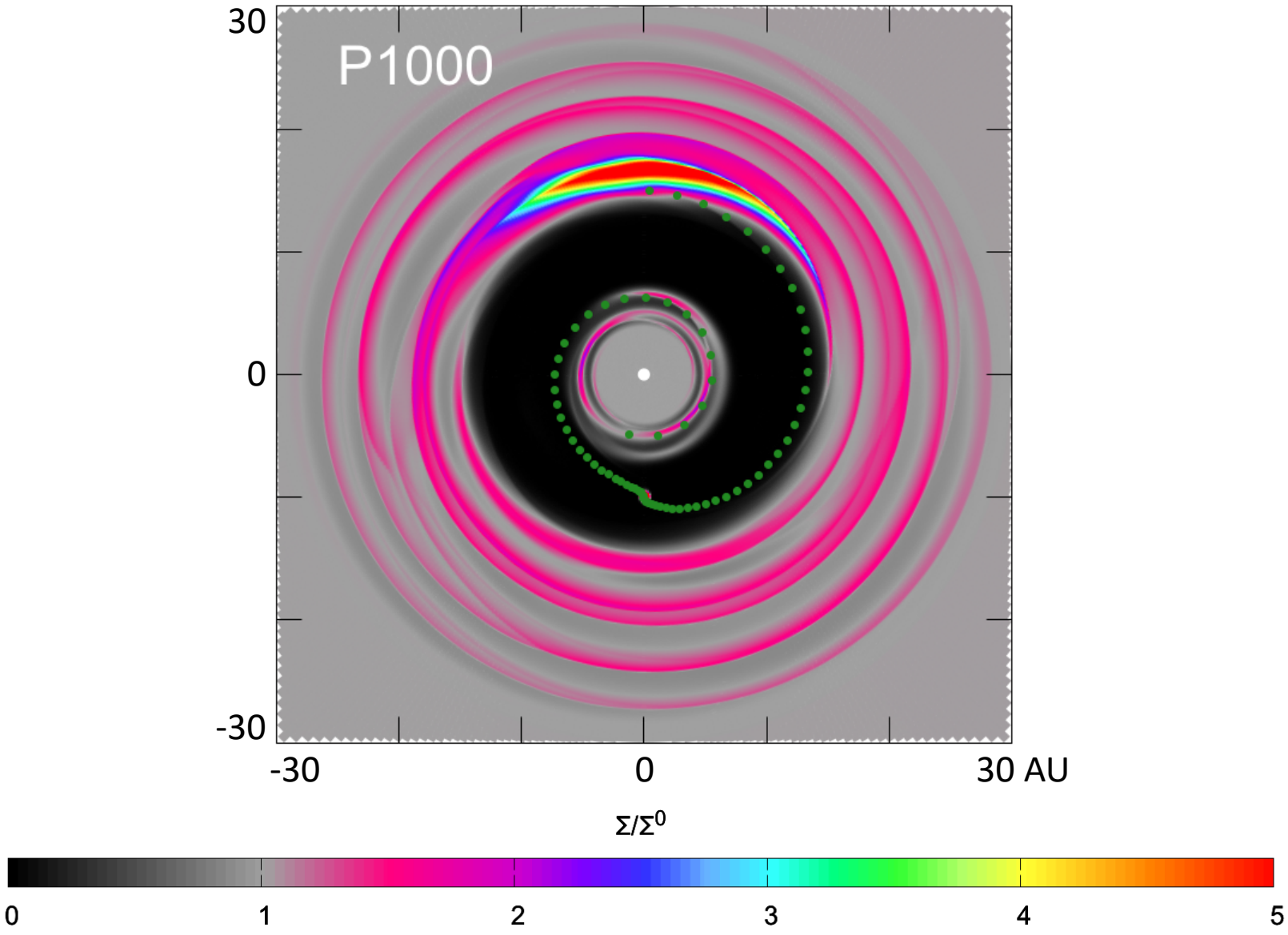

20160229ASU/timescales.sm
1000
100
10
1
Timescale / Years
Thermal
Dynamical
1
10
100
Distance from Star / AU

Poor Man's Radiation Hydrodynamics

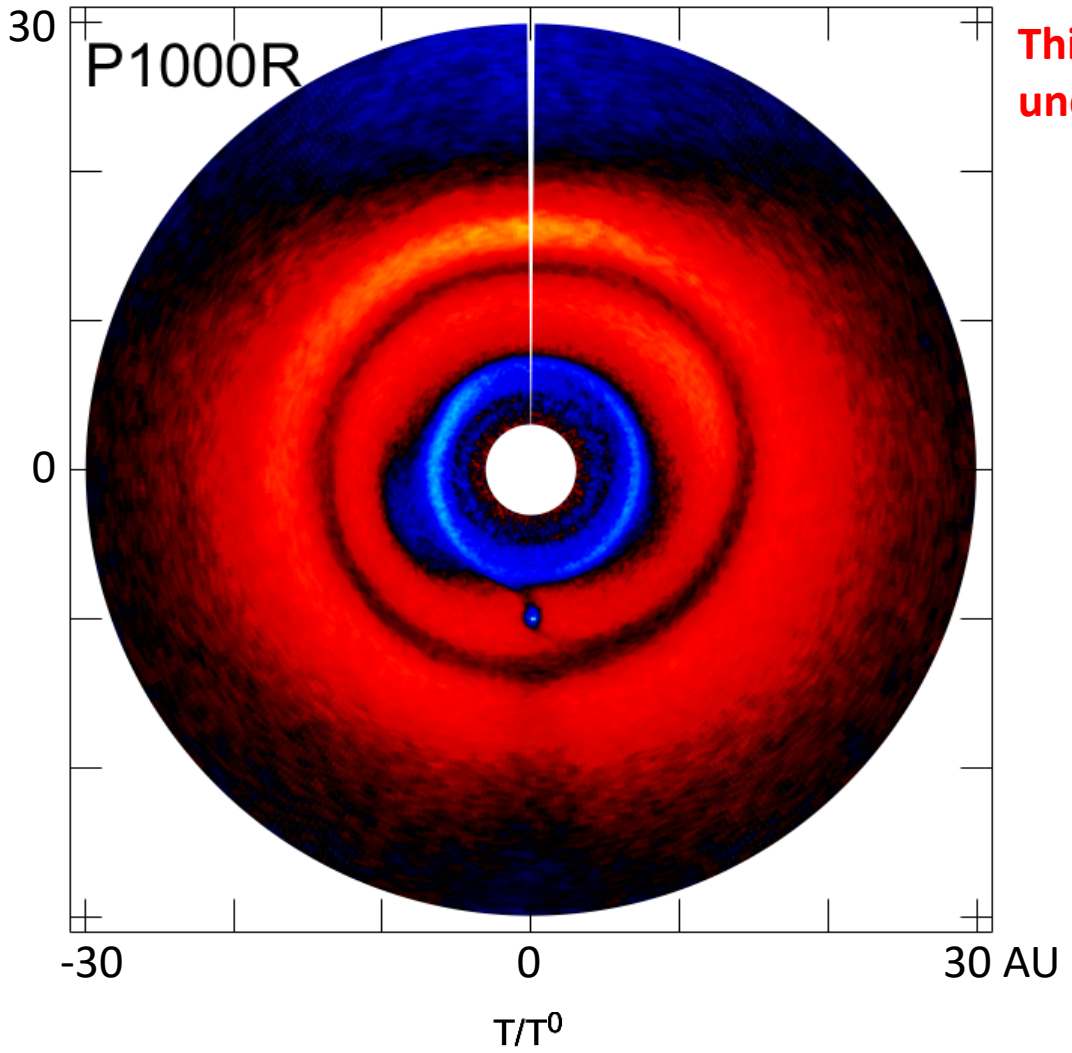
$$\Delta h = (h_{eq} - h) \frac{\Delta t}{\max\left(t_{dy}, t_{th}\right)}$$


2-D Hydro
With Planet,
Fixing T(R),
Gives Σ(R,ϕ)
3-D Radiative
Transfer for
Temperature
Time-step
3-D Density
towards HSE

Surface Density Ratio With 1000-Earth-Mass Planet

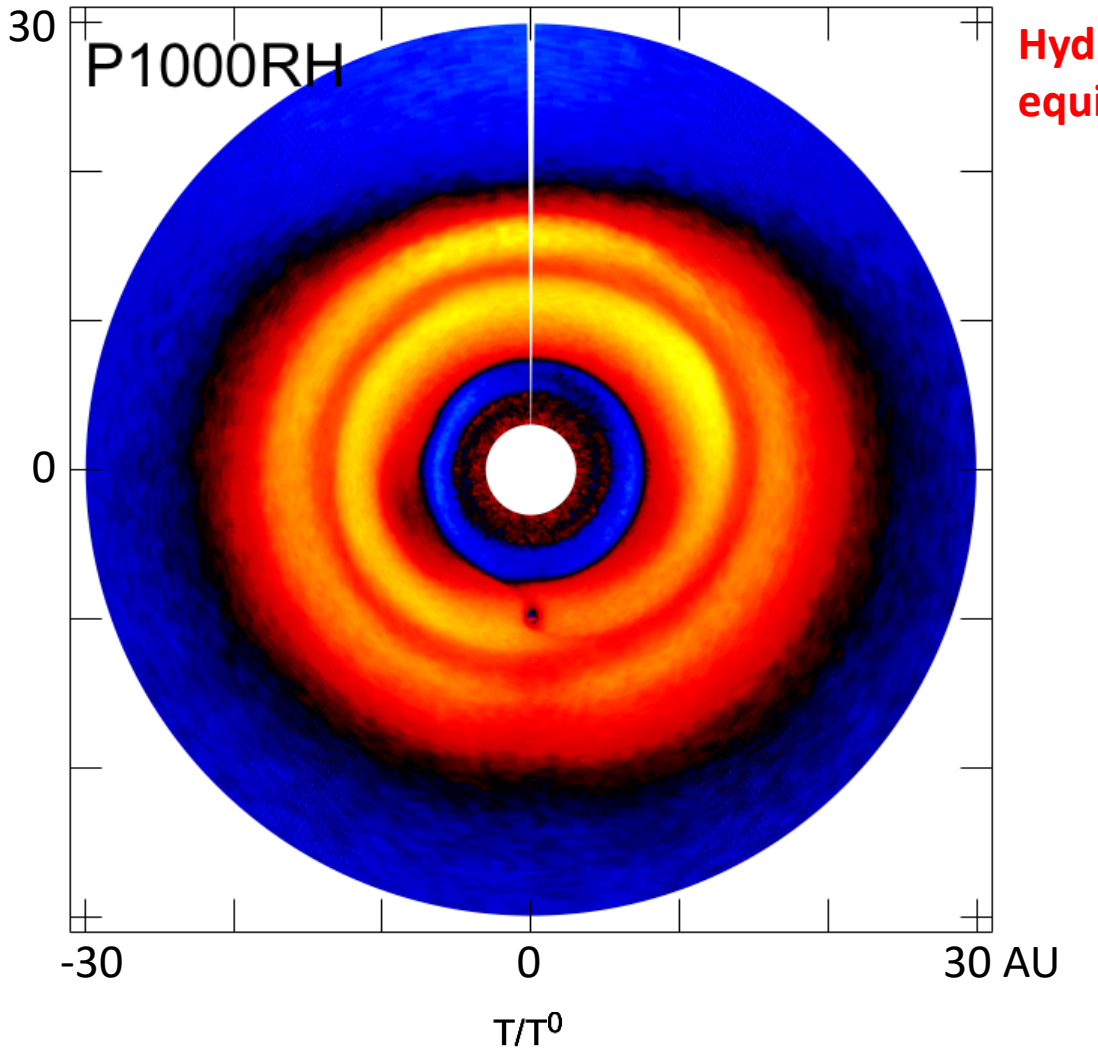


Midplane Temperature Ratio With 1000-Earth-Mass Planet



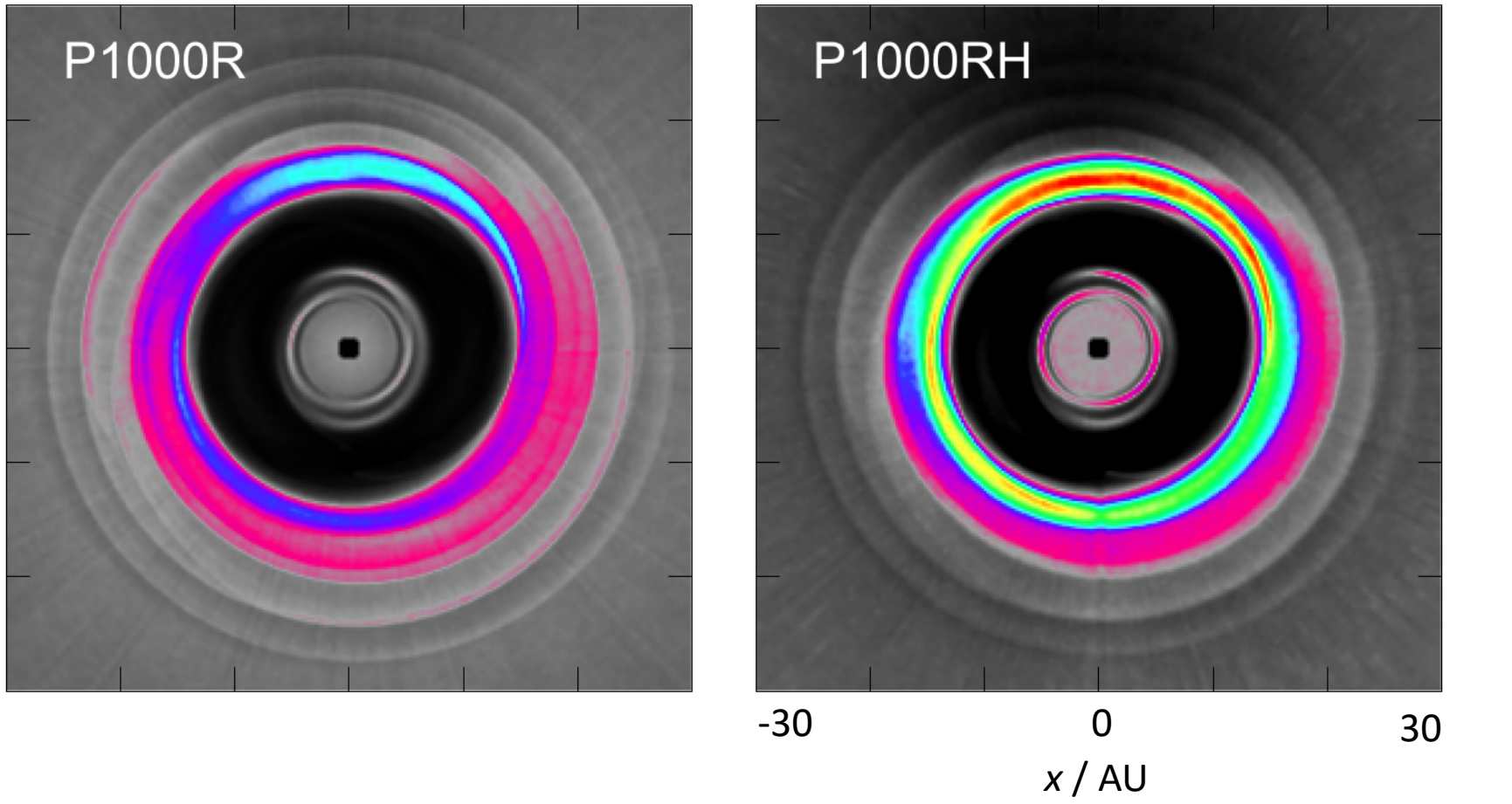
Thickness undisturbed

Midplane Temperature Ratio With 1000-Earth-Mass Planet



Hydrostatic equilibrium

The disk's response to starlight heating drastically changes the appearance in scattered light!



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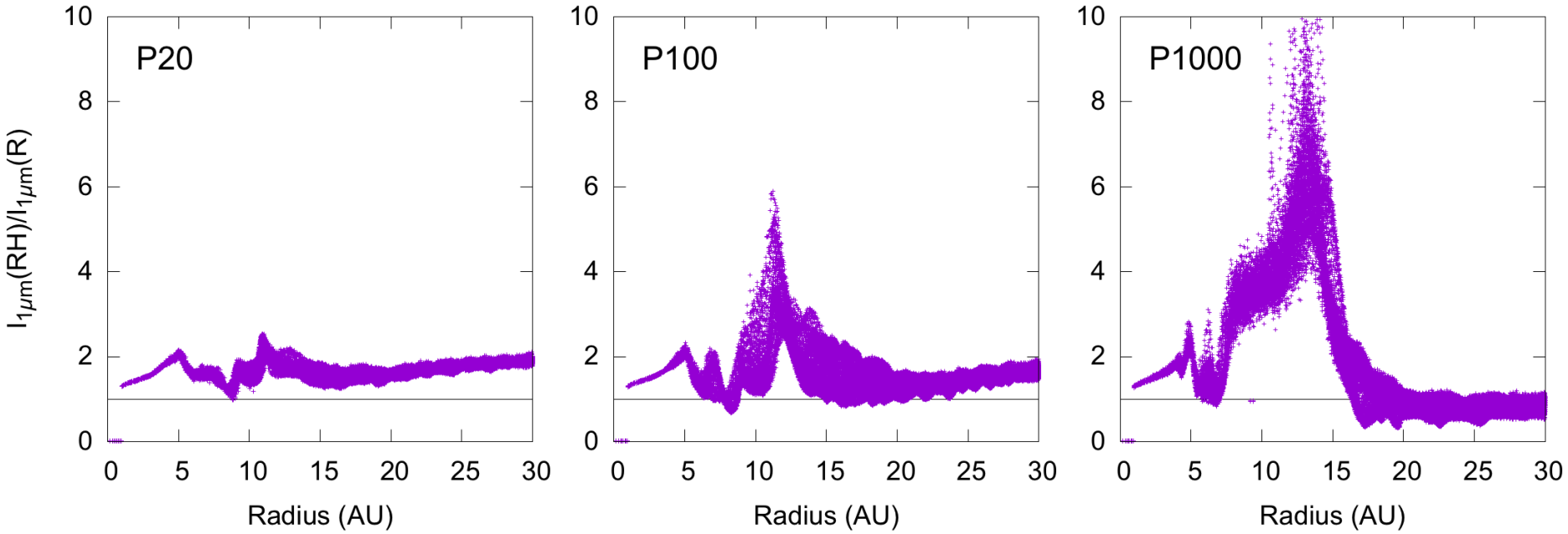
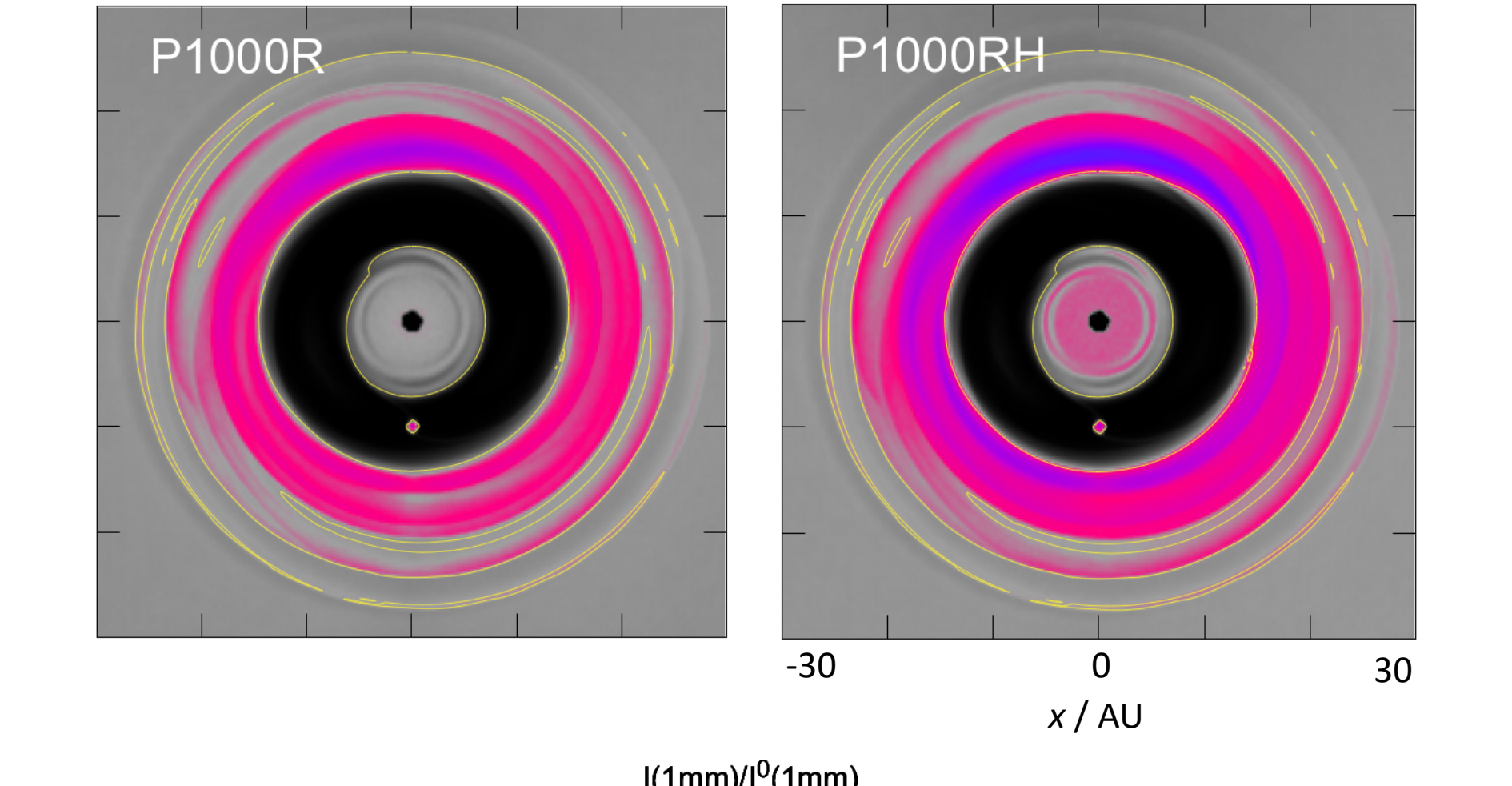


The disk's response to starlight heating somewhat changes the appearance in millimeter continuum.



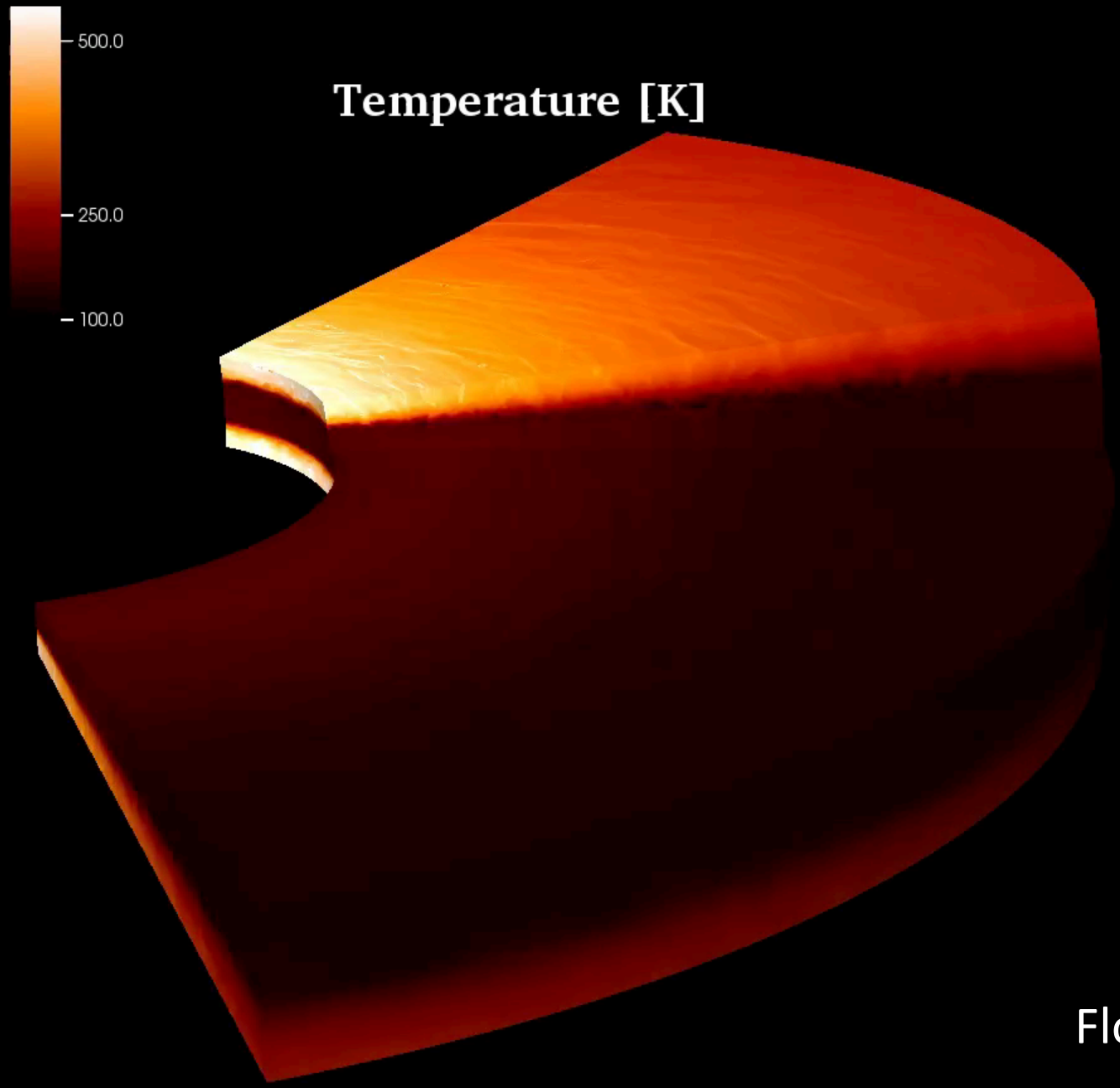
Summary

Reliably predicting young planets' signatures requires treating disks' response to the starlight falling on the planet-raised features.

The equilibrium response:

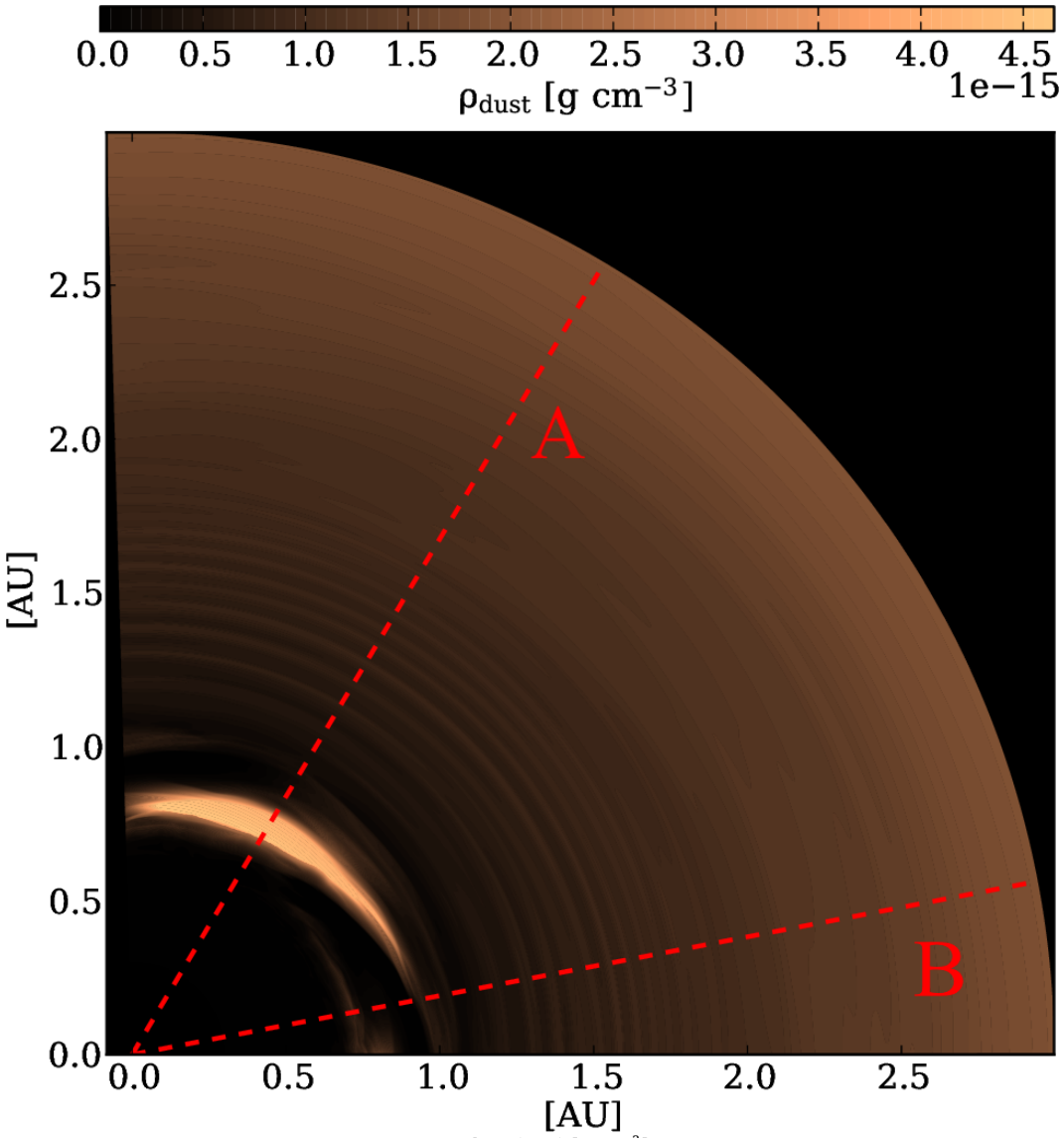
- **Greatly increases the scattered-light contrast at the gap's outer edge.**
- **Reduces the outer spiral arm's brightness in scattered light.**
- **Reshapes the millimeter continuum emission.**

Dynamics Faster Than Heating/Cooling

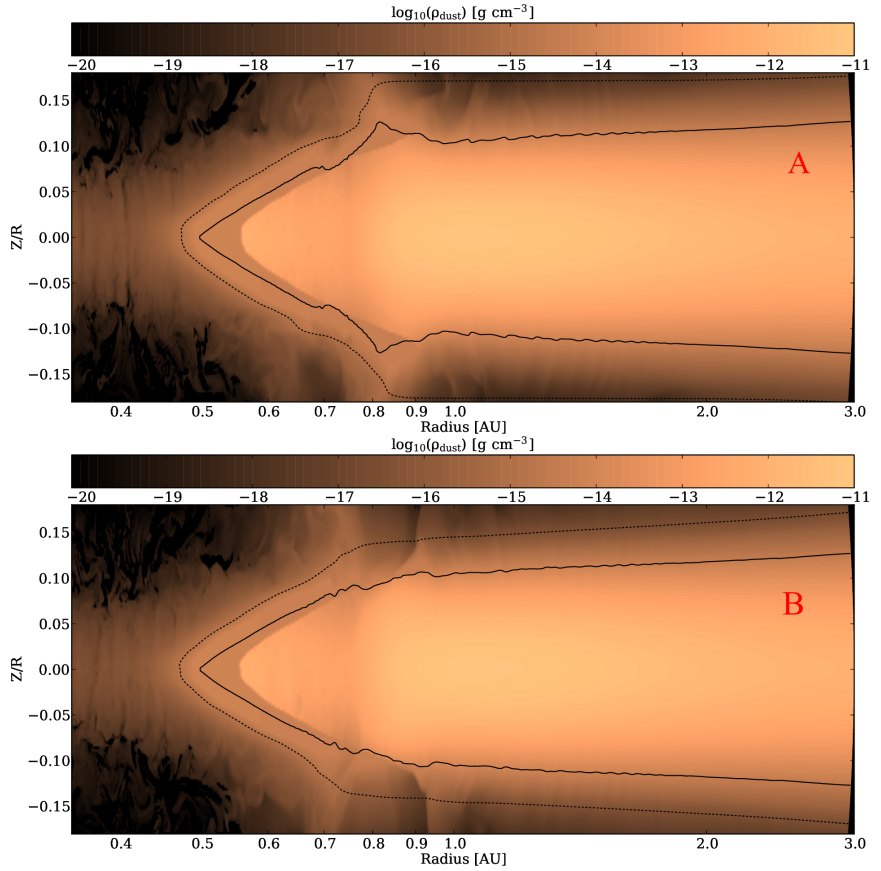


Flock+ 2013

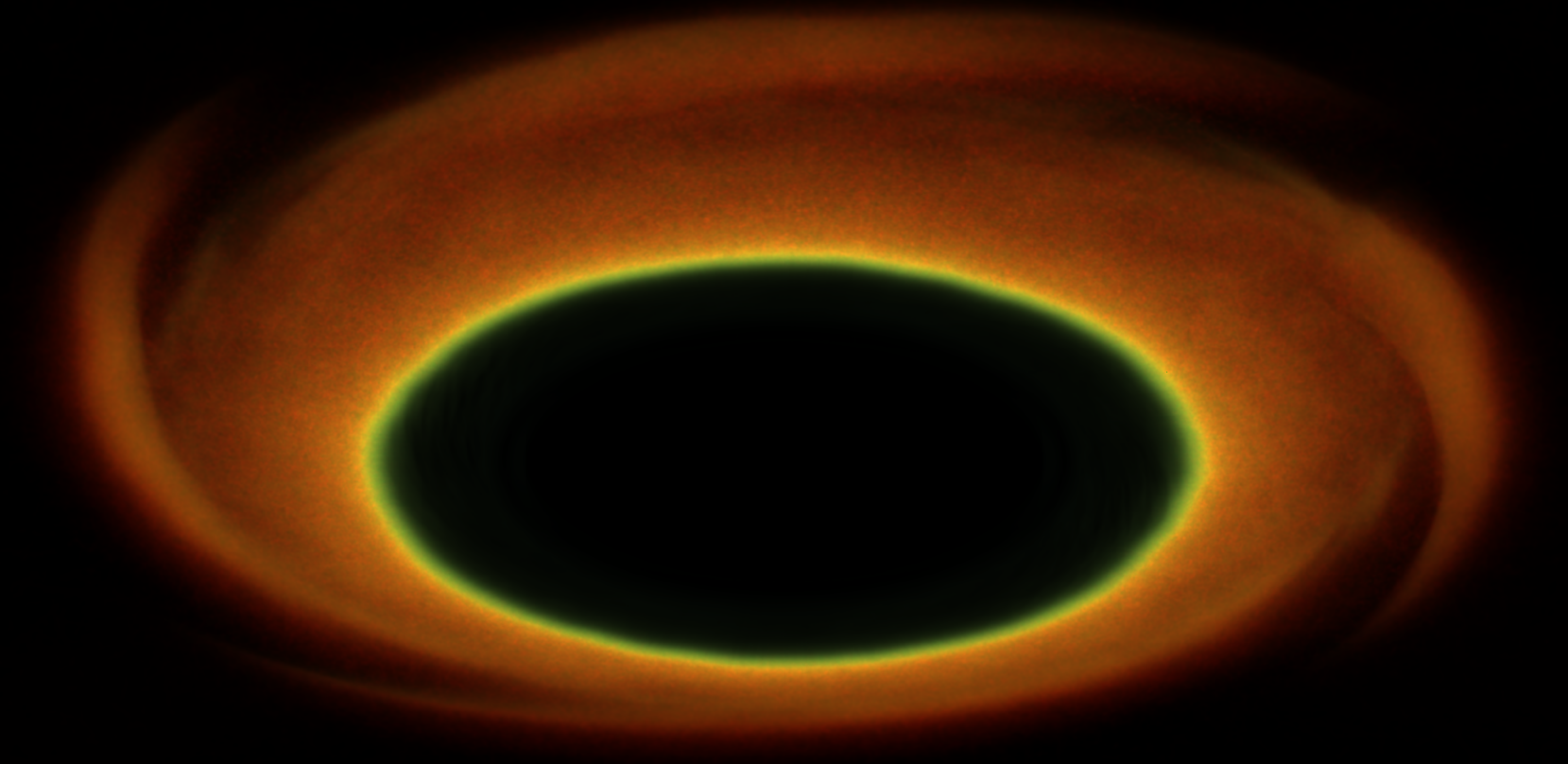
Heating/Cooling Feed Back on Dynamics



Flock+ 2017a

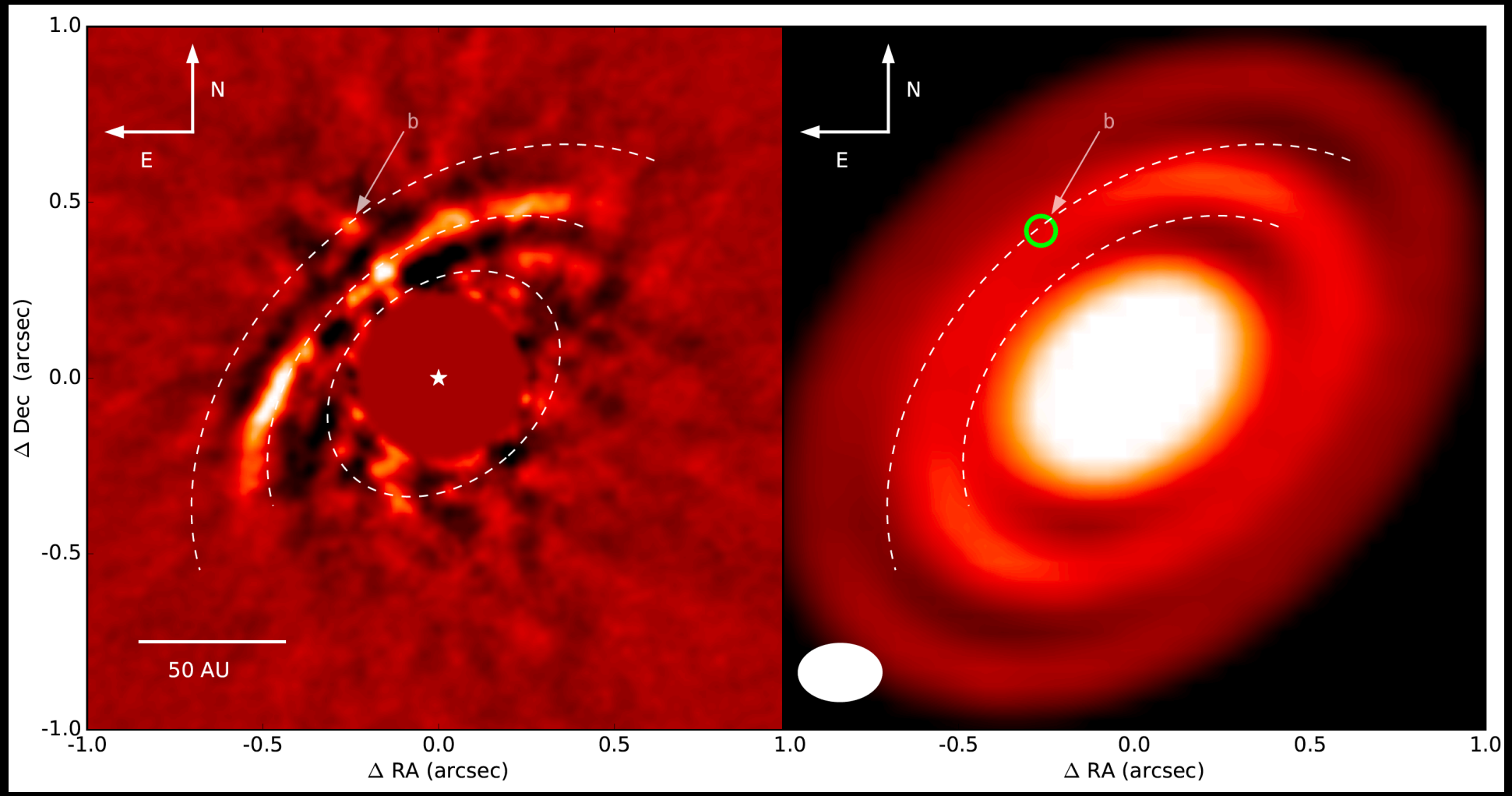


Heating/Cooling Feed Back on Dynamics



Flock+ 2017a

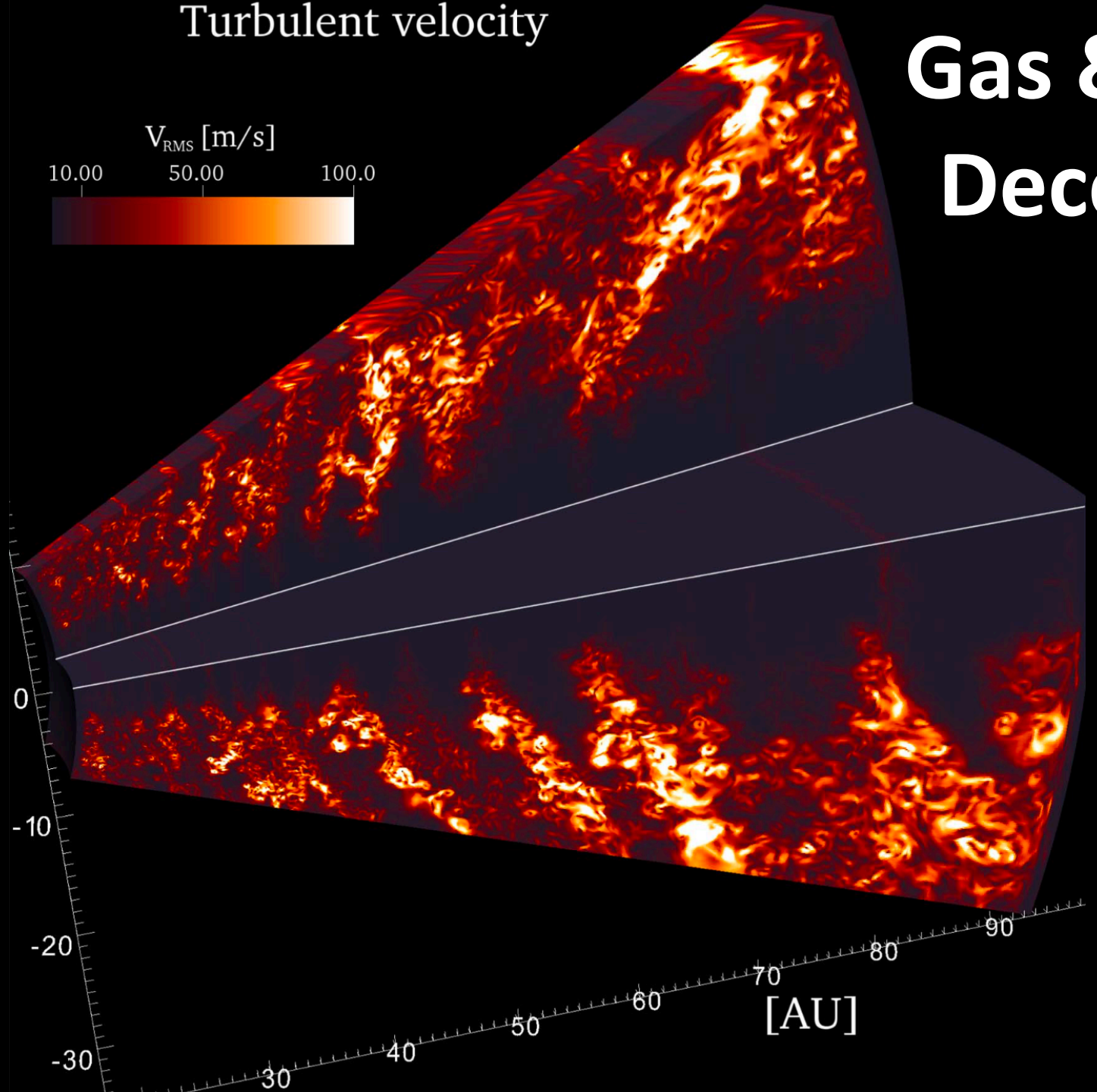
Gas & Dust Decouple



HD163296 at 3.7μm and 1mm – Guidi+ 2018

Grains settle, grow, fragment…

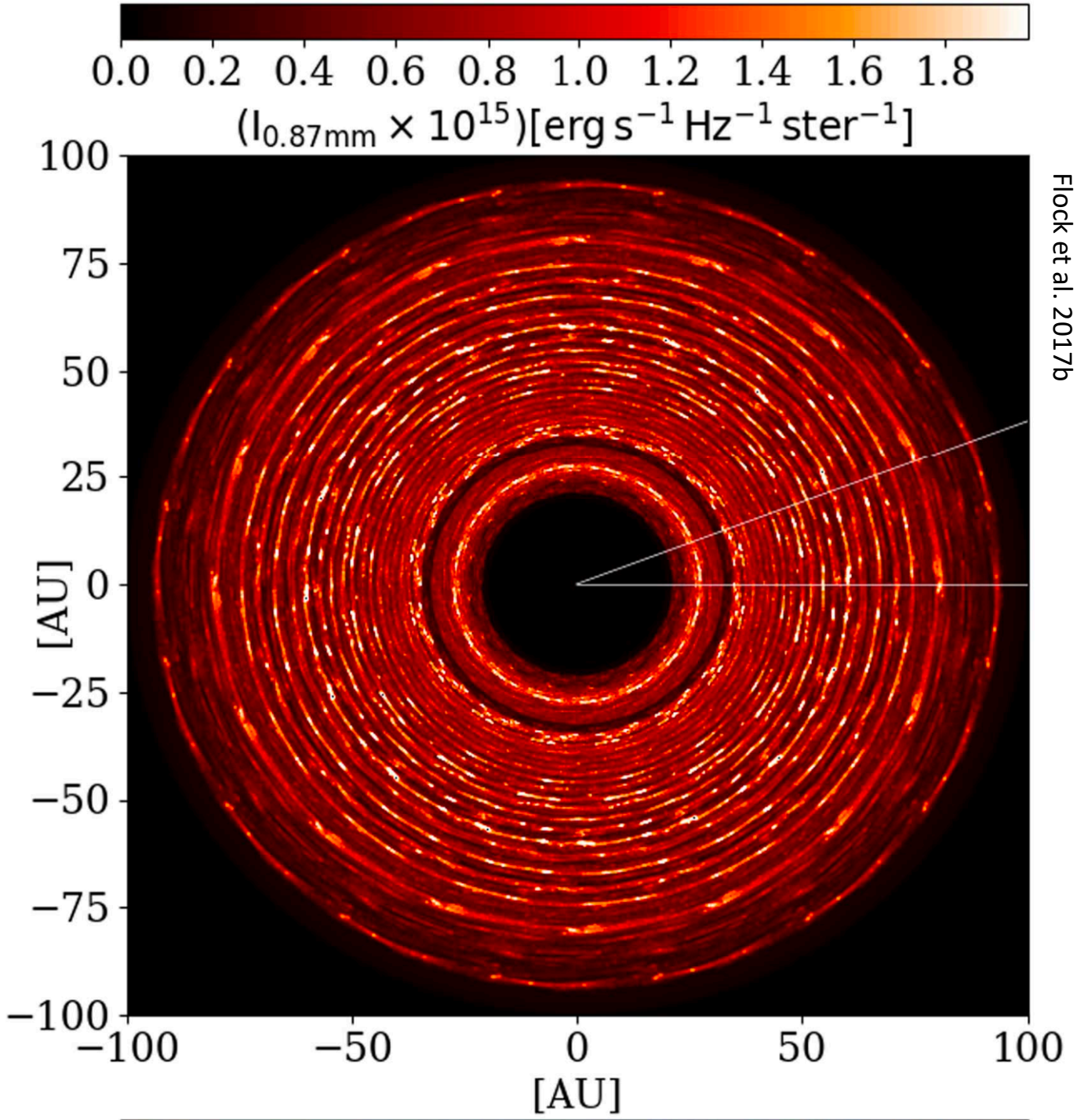
Dust storm over Adelaide, Australia by SydneyOats via flickr with CCby2.0



Gas & Dust Decouple

Flock+ 2017b

VSI Makes Rings



Flock et al. 2017b

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- **Reduces the outer spiral arm's brightness in scattered light.**
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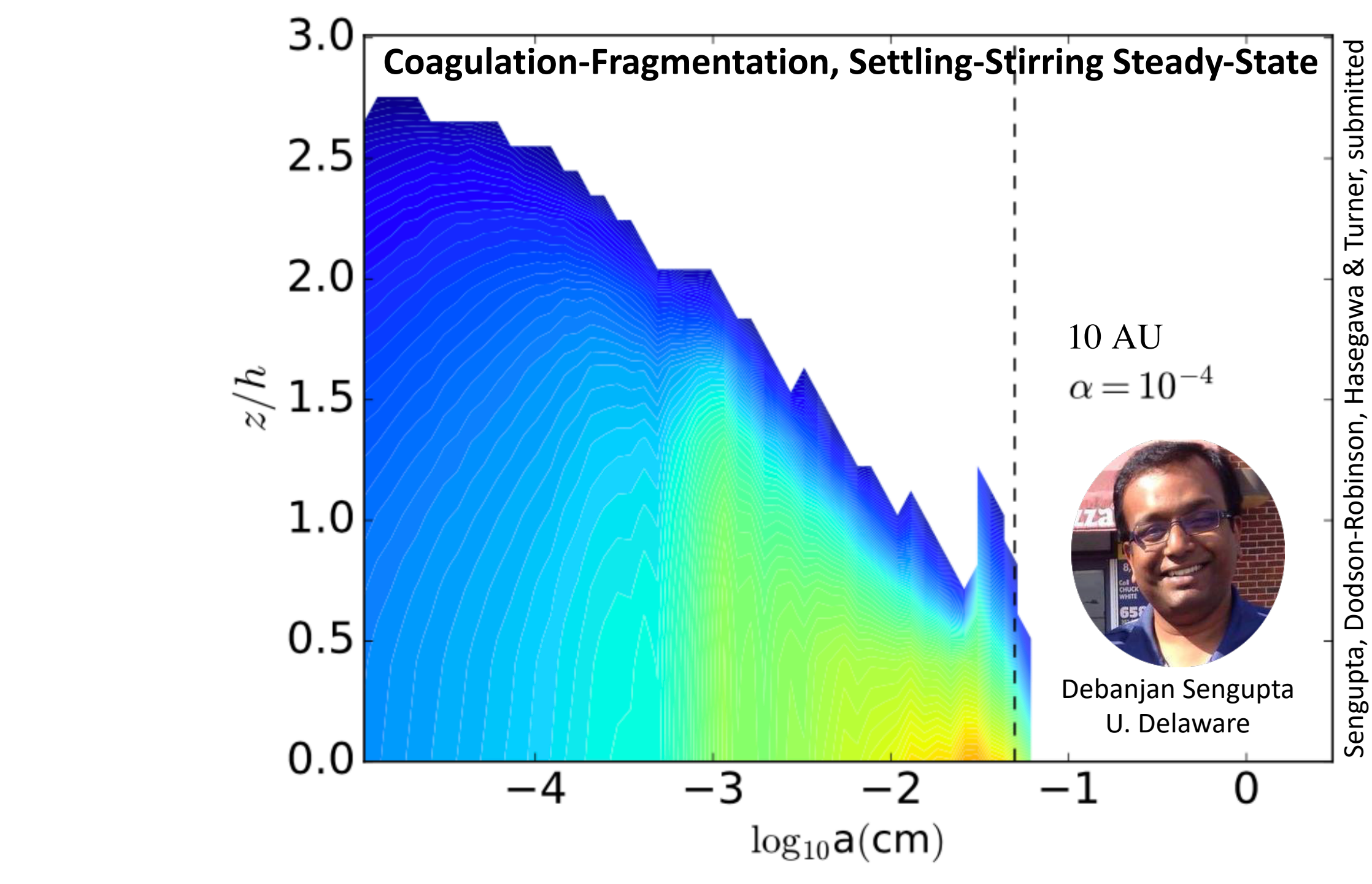
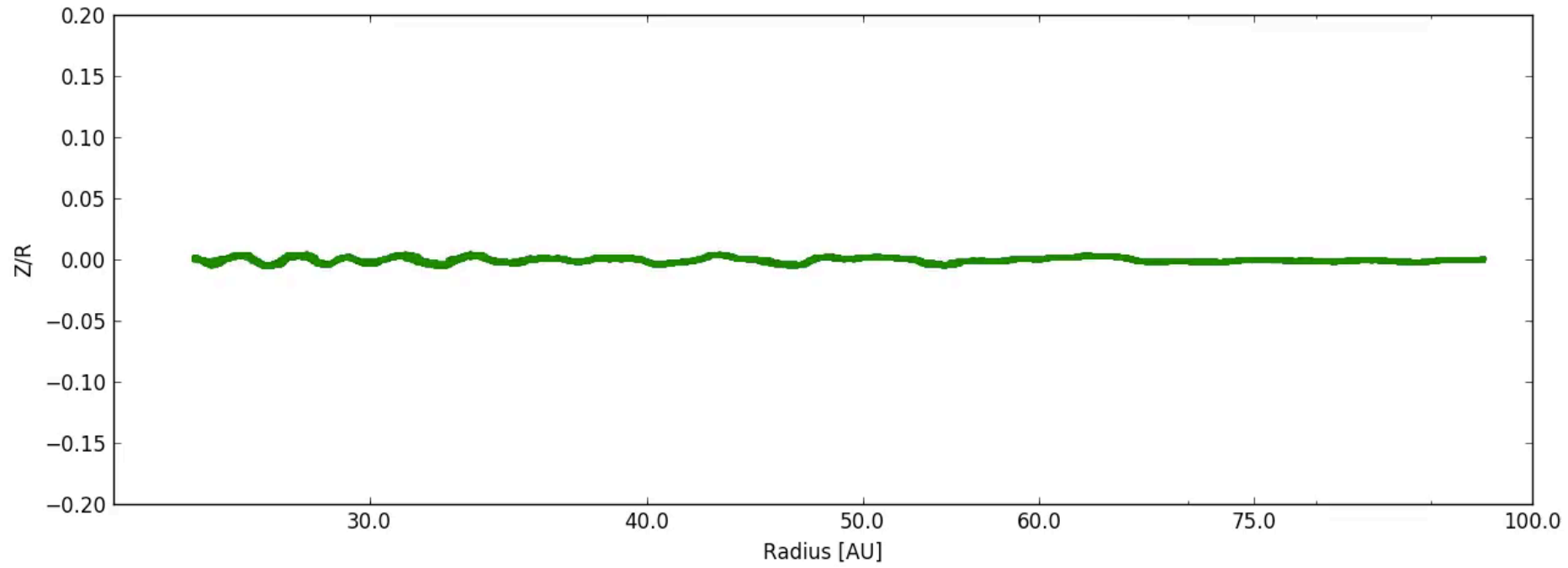
Backup



Debanjan Sengupta
U. Delaware

Sengupta, Dodson-Robinson, Hasegawa & Turner, submitted

Gas & Dust Decouple



Flock+ 2017b